FORM PTO-1390 (REV-11-2000) U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE	ATTORNEY 'S DOCKET NUMBER
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371	U.S. APPLICATION NO. (If known, see 37 CFR 1 5) **09/913840**

INTERNATIONAL APPLICATION NO. PCT/GB00/00174	INTERNATIONAL FILING DATE 24 January 2000	PRIORITY DATE CLAIMED 22 January 1999

TITLE OF INVENTION
OFDM RECEIVER WITH ADAPTIVE EQUALISER

APPLICANT(S) FOR DO/EO/US
Simon ARMOUR, David Roger BULL, and Andrew Robert NIX

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST submission of items concerning a filing under 35 U.S.C. 371.**

2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 36 U.S.C. 371.

3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f). The submission must include items (5), (6), (9) and (21) indicated below.

4. ☐ The US has been elected by the expiration of 19 months from the priority date (Article 31).

5. ☒ A copy of the International Application as filed (35 U.S.C. 37(c)(2))
    a. ☒ is attached hereto (required only if not communicated by the International Bureau).
    b. ☐ has been communicated by the International Bureau
    c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).

6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
    a. ☐ is attached hereto.
    b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).

7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).
    a. ☐ are attached hereto (required only if not communicated by the International Bureau).
    b. ☐ have been communicated by the International Bureau.
    c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
    d. ☐ have not been made and will not be made.

8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)).

9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).

10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.

12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.

13. ☐ A FIRST preliminary amendment.

14. ☐ A SECOND or SUBSEQUENT preliminary amendment.

15. ☐ A substitute specification.

16. ☐ A change of power of attorney and/or address letter.

17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13*ter*.2 and 35 U.S.C. 1.821 – 1.825.

18. ☐ A second copy of the published international application under 36 U.S.C.

19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).

20. ☐ Other items or information:

page 1 of 2

I/S/ Application no. (if known, see 37 CFR 1.5) 09/913840	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER

21. ☐ The following fees are submitted:	CALCULATIONS PTO USE ONLY

BASIC NATIONAL FEE (37 CFR 1.492(A) (1) – (5)):

Neither international preliminary examination fee (37 CFR 1.492)
nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO
and International Search Report not prepared by the EPO or JPO $1000.00

International preliminary examination fee (37 CFR 1.482) not paid to
USPTO but International Search report prepared by the EPO of JPO $860.00

International preliminary examination fee (37 CFR 1.482) not paid to
USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO $710.00

International preliminary examination fee (37 CFR 1.482) paid to
USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) $690.00

International preliminary examination fee (37 CFR 1.482) paid to
USPTO and all claims satisfied provisions of PCT Article 33(1)(4) $100.00

ENTER APPROPRIATE BASIC FEE AMOUNT = 860.00	$	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☒ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	**$130.00**	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	$	
Total claims	9 - 20 =		x $18.00	$	
Independent claims	3 -3 =		x $80.00	$	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ 270.00	$	

TOTAL OF ABOVE CALCULATIONS =	$990.00	
☐ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2. +	$	
SUBTOTAL =	$990.00	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFT 1.492(f).	$	
TOTAL NATIONAL FEE =	990.00	
Fee for recording the enclosed assignment (37 CFR 1.2(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +	$	
TOTAL FEES ENCLOSED =	$990.00	

Amount to be refunded:	$	
charged:	$	

a. ☐ A check in the amount of $_____ to cover the above fees is enclosed.

b. ☒ Please charge my Deposit Account No. 20-1430 in the amount of $990.00 to cover the above fees.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 20-1430. A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Two Embarcadero Center Eighth Floor
San Francisco, CA 94111-3834

SIGNATURE

Chad S. Hilyard
NAME

40,647
REGISTRATION NUMBER

OFDM RECEIVER WITH ADAPTIVE EQUALISER

This invention relates to a receiver, and in particular to an OFDM receiver, and to an adaptive equalizer for use in such a receiver and to a method of training the equalizer.

The European digital terrestrial television standard, DVB-T, specifies orthogonal frequency division multiplexing, OFDM as the modulation scheme.

In conventional OFDM systems, multipath radio transmission channels cause delay spread distortion of the transmitted signal. Although adaptive equalizers can be used in many applications to cancel out delay spread distortion, existing designs for OFDM receivers and adaptive equalizers are generally incompatible, although it has been proposed to use a number of equalizers acting in parallel on respective sub-bands of the OFDM signal.

Therefore, existing designs for OFDM systems employ guard intervals to combat the effects of delay spread. Each transmission period includes a period during which useful information is transmitted, and a guard interval, during which no useful information is transmitted. Thus, use of a guard interval reduces efficiency of the transmission, and less data can be transmitted within a given radio frequency bandwidth.

The present invention relates to an OFDM receiver including an adaptive equalizer, which attempts to overcome the incompatibility of existing designs of OFDM receivers and adaptive equalizers.

According to a first aspect of the present invention, there is therefore provided a receiver as defined in claim 1.

According to a second aspect of the present invention, there is therefore provided an equalizer as defined in claim 6.

According to a third aspect of the present
invention, there is therefore provided a method as
defined in claim 7.

For a better understanding of the present
5   invention, reference will now be made to the
accompanying drawings, in which:-

Figure 1 shows a first receiver in accordance with
the invention;

Figure 2 shows a first equalizer in accordance
10   with the invention;

Figure 3 shows a second equalizer in accordance
with the invention;

Figure 4 shows a second receiver in accordance
with the invention.

15   **DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS**

As Shown in Figure 1, a transmitted analog OFDM
symbol is received over a radio frequency channel 2
having unknown and time-varying characteristics, and is
subject to the addition of noise.

20   The receiver therefore takes an input signal $y_1'(t)$
in an input device 4, where it is demodulated, A-D
converted and down-sampled to give a time domain vector
$y'(n,1)$. The received sequence $y'(n,1)$ is filtered by
an adaptive equalizer 6 to produce a time-domain
25   sequence $z'(n,1)$.

The time domain sequence output from the
equalizing filter 6 is input to a guard extraction
device 8 to form an output $z(n,1)$, An advantage of the
present invention is that the need for a guard interval
30   may be reduced or eliminated. The guard extraction
device 8 is therefore required only if it is needed if
a guard interval is used by the transmitter which is in
use.

A Fast Fourier Transform (FFT) 10 is then applied
35   to $z(n,1)$ to produce a frequency domain vector $Z(k,1)$.

In this embodiment of the invention, the frequency

domain vector is supplied to a channel estimator 12
which derives an estimation of the radio channel's
frequency response and compensates according to this
estimate. In an alternative embodiment, the channel
estimator may be omitted.

     The vector is then supplied to an output device 14
to produce a data output. The output device 14 may be
nothing more than a hard limiter, putting the data into
a useable form. However, any interleaving, coding,
signal mapping or other error control strategies
applied in the transmitter are reversed in the output
device 14 and exploited to correct any errors and
produce the output data sequence. The output data,
which is the best possible estimate of the data content
of the transmitted signal is then applied to a feedback
loop, and processed to form the best possible estimate
of the transmitted sequence. Specifically, the data
output is applied to a device 16 which interleaves,
codes and maps the data in an identical manner to that
performed at the transmitter to produce the frequency
domain sequence $W(k,l)$.

     The frequency domain sequence is input to an
inverse Fourier transform device 18 and the output
$w(n,l)$ of this device is applied to a guard interval
insertion device 20 to insert a guard interval
corresponding to any that was added in the transmitter
to generate a sequence $w'(n,l)$. In effect, the data
output is processed in the feedback loop to effectively
attempt to reconstruct the OFDM symbol that was
generated at the transmitter, and hence $w'(n,l)$ is an
estimate of the transmitted sequence $x'(n,l)$.

     The estimate $w'(n,l)$ is then input to the
equalizing filter 6 to enable decision directed
adaptation of the tap coefficients thereof.

     Each updated estimate of an OFDM symbol, made up
of a number of sub-symbols, is available to the

equalizer only after all sub-symbols of one OFDM symbol
have been received.

Figure 2 shows the equalizer of the present
invention. As is generally conventional, the equalizer
5   consists of two shift register sections: a feedforward
section 32 that stores future transmission symbols and
the current transmission symbol and a feedback section
34 that stores previous transmission symbols. The
length of the feedforward section is (J_1+1) symbols and
10   the length of the feedback section is J2 symbols. The
received sequence $y'(n,1)$ is input, the value of each
stored symbol is multiplied by a tap coefficient $c(j)$,
and the results are summed to form the equalizer output
$z'(n,1)$.

15   The tap coefficients $c(j)$ are updated according to
the LMS adaptation algorithm. As is known, the LMS
algorithm adapts the equalizer taps according to the
error measure between the equalizer output symbols and
an estimate of the transmitted symbols. The estimate
20   of the transmitted symbols can be achieved either by
means of a training sequence or by decision directed
adaptation.

Adaptation according to a training sequence
requires the transmission of symbols of which the
25   equalizer has prior knowledge. This training mode
allows adaptation according to an error free estimate
of transmitted symbols but results in no data
throughput.

Decision directed adaptation feeds back output
30   data to estimate the transmitted symbols. This estimate
is not necessarily error free but does allow for data
throughput.

In practice, the two techniques are combined. An
initial training sequence approximately adapts the
35   equalizer and reduces equalizer output error
sufficiently that decision directed adaptation may

provide an adequate error measurement for further
adaptation. During decision directed adaptation the
equalizer further adapts both to `fine tune' its action
and to track any relatively small time variation in the
5   radio channel.

The equalizer of Figure 2 is generally similar to
a conventional equalizer, although there are
differences as follows:-

Symbols input to the feedback register 32 during
10   decision directed operation do not come directly from
the decision device but rather from the feedback
vector.

Symbols used to calculate error during decision
directed operation come similarly from the feedback
15   vector rather than direct from the decision device.

Additional buffers 36, 38 for both feedforward and
feedback sections further store past symbols beyond the
duration of the feedforward/feedback sections. These
additional stored values are required for decision
20   directed adaptation

During decision directed mode the tap coefficients
are not updated at intervals of the sub-symbol period,
but rather at the OFDM symbol period, regarding one
OFDM symbol as made up a group of sub-symbols.

25   However, the LMS calculation is performed in the
LMS calculation processor 40 to calculate adjustments
corresponding to intervals of the sub-symbol period
with the sum of all calculated adjustments being made
at intervals of the OFDM symbol period.

30   The equalizer output may be directly input to the
feedback section thereof.

These additional features, which apply during a
decision directed (or data derived) operation, enable
the equalizer to operate within the OFDM receiver
35   architecture.

More detailed explanation of all these features is

given below.

Since the equalizer operates on the received time
domain sequence its output is also a time domain
sequence. Data in the OFDM modem is in the frequency
domain and hence the equalizer output must be Fourier
Transformed (with any guard interval first being
removed) prior to the decision process. Thus, the
output of the equalizer cannot be applied directly to
the decision device. Similarly the decision device
output cannot be fed back directly to the equalizer.
The feedback vector is fed back instead. If the
equalizer is adapting according to a training sequence
this is irrelevant, since the training sequence itself
is an error free estimate of the transmitted sequence
and can be input to the equalizer's feedback section.
Furthermore, the decision device output cannot be used
to calculate the output error used in the LMS
adaptation algorithm and the feedback vector is again
used instead.

The additional symbol buffering and the changes to
the adaptation process in decision directed mode are
necessary since the parallel transmission undertaken in
OFDM results in the group post-decision data sub-
symbols making up one OFDM symbol being simultaneously
output at intervals of the OFDM symbol period. (By
contrast, a single carrier system outputs individual
symbols at intervals of the symbol period.) This
restriction imposed by the parallel transmission
prevents decision directed adaptation during OFDM
symbols. It also prevents feedback values becoming
available to the equalizer until the end of the OFDM
symbol.

Therefore, instead of adapting the equalizer with
each transmission sub-symbol, all transmission symbols
forming the OFDM symbol are clocked through the
equalizer with the tap coefficients remaining constant

and the equalizer output is input directly into the feedback section. At the end of each OFDM symbol the past and future transmission symbols that were stored in the feedforward and feedback sections at the start of the OFDM symbol are recovered from the buffers. Since the tap coefficients remain constant throughout the OFDM symbol the equalizer is effectively returned to its state at the start of the OFDM symbol. The OFDM symbol is then clocked into the equalizer once more with the feedback OFDM symbol now available both for determination of error and input to the feedback section. This process enables the adaptation steps that had not previously taken place to be completed and replaces the fed back output symbols with post decision estimates of the transmitted symbols as provided by the feedback OFDM symbol.

This method of operation described above allows both the feedforward and feedback stages of the equalizer to have numbers of taps which are integer multiples of the length of the extended OFDM symbol, which is considered to be (N+M), with N the number of transmission symbols in the useful period of an OFDM symbol, and M the number of transmission symbols in the guard period. In this illustrated embodiment, these numbers of taps are equal to the length of the extended OFDM symbol.

The equalizer output is then given by:-

$$z'(n,l) = \sum_{j=-J_1}^{-J_1+n} c(j)y'((n-j-(N+M)),l+1) + \sum_{j=-J_1+n+1}^{0} c(j)y'((n-j),l)$$

$$+ C_{out}(n)\sum_{j=1}^{n} c(j)z'((n-j),l) + \sum_{j=n+1}^{J_2} c(j)w'((n+(N+M)-j),l-1)$$

where:

$C_{out}(n) = 0$ for $n = 0$

and:

$C_{out}(n) = 1$ for $n \neq 0$

The equalizer is then adapted according to the LMS algorithm, which in this case is defined as follows:-

During Training Mode:

$$c(j, n+1, l) = c(j, n, l) + \Delta\varepsilon'(n, l)y'^*((n - j - (N + M)), l + 1)$$

for　　$-J_1 \leq j \leq -J_1 + n + 1$

$$c(j, n+1, l) = c(j, n, l) + \Delta\varepsilon'(n, l)y'^*((n - j), l)$$

for　　$-J_1 + n + 2 \leq j \leq 0$

$$c(j, n+1, l) = c(j, n, l) + \Delta\varepsilon'(n, l)x'^*((n - j), l)$$

for　　$1 \leq j \leq n$

$$c(j, n+1, l) = c(j, n, l) + \Delta\varepsilon'(n, l)x'^*((n + (N + M) - j), l - 1)$$

for　　$n + 1 \leq j \leq J_2$

$$\varepsilon'(n, l) = x'(n, l) - z'(n, l)$$

During Decision Directed Operation

$$c(j, n, l+1) = c(j, n, l) + C_{j'}(j) \sum_{n=0}^{N+M+j-1} \Delta\varepsilon'(n, l)y'((n - j), l) + \sum_{n=N+M+j}^{N+M-1} \Delta\varepsilon'(n, l)y'((n - (N + M) - j), l + 1)$$

for　　$-J_1 \leq j \leq 0$

$$c(j, n, l+1) = c(j, n, l) + \sum_{n=0}^{j-1} \Delta\varepsilon'(n, l)w'((n + (N + M) - j), l - 1) + C_{jb}(j) \sum_{n=j}^{N+M-1} \Delta\varepsilon'(n, l)w'((n - j), l)$$

for　　$1 \leq j \leq J_2$

$$\varepsilon'(n, l) = w'(n, l) - z'(n, l)$$

where:

$$C_{ff}(j) = 0 \quad \text{for} \quad -j = N + M$$

and:

$$C_{ff}(j) = 1 \quad \text{for} \quad -j \neq N + M$$

$$C_{ff}(j) = 0 \quad \text{for} \quad j = N + M$$

and:

$$C_{ff}(j) = 1 \quad \text{for} \quad j \neq N + M$$

Δ Equalizer step constant

$c(j,n,l)$ Equalizer tap vector in OFDM system

$\varepsilon(n,l)$ Equalizer output error vector in OFDM system

Figure 3 shows an alternative equalizer in accordance with the invention. It corresponds generally to that of Figure 2, except that the symbols input to the equalizer's feedback section 34 are zero symbols. This prevents the feedback of noise bearing symbols into the equalizer but, as a consequence, the equalizer no longer cancels delay spread distortion from within the same OFDM symbol. However this will still allow for an effective transmission strategy since, for example, where a guard interval is employed, delay spread interference within the same OFDM symbol does not cause inter-carrier interference (ICI). Thus, an equalizer with zero symbol feedback may be combined with a channel estimation process to achieve cancellation of delay spread distortion without the need to feed back pre-decision transmission symbols.

Thus, in Figure 3, compared with Figure 2, the feedback path from the equalizer output directly to the feedback section is replaced by a zero symbol source.

The equalizer output then becomes:-

$C_{out}(n) = 0$, for all n.

The method of tap adaptation in the equalizer of figure 3 is the same as that described above with reference to Figure 2.

The equalizer is no longer required to cancel all delay spread distortion and hence the equalizer output is not expected to approximate the transmitted sequence. The receiver is therefore as shown in Figure 4, as the feedback vector must be adjusted to compensate the uncombatted distortion. This is achieved by reversing the channel compensation process in the feedback path. Thus the channel estimate produced by the channel estimator 12 is applied in reverse to the output of mapping and interleaving device 16. This achieves a feedback vector which is suitably adjusted.

There is thus described a receiver, and an equalizer, which allow adaptive equalization of OFDM signals, with a consequent improvement in the noise in the received signals.

CLAIMS

1.   An OFDM receiver, comprising:

a received signal processor, for demodulating, A-D converting, and down-sampling received signals to form a time domain digital signal vector;

an equalizer, having at least a feedback section and having a plurality of tap coefficients, the equalizer acting on the time domain digital signal vector to form a filtered time domain sequence;

a Fast Fourier Transform processor, for acting on the filtered time domain sequence to form a frequency domain vector;

an output device, for converting the frequency domain vector into an output data signal;

an inverse Fast Fourier Transform processor, for acting on the output data signal to form an estimate of the transmitted sequence;

wherein the estimate of the transmitted sequence is supplied as an input to the equalizer to enable decision directed adaptation of the tap coefficients thereof, and further as an input to the feedback section of the equalizer.

2.   An OFDM receiver as claimed in claim 1, further comprising:

a guard extraction device, for extracting any guard sequence from the filtered time domain sequence before processing by the Fast Fourier Transform processor; and

a guard insertion device, for inserting a guard interval, corresponding to that removed by the guard extraction device, into the estimate of the transmitted sequence supplied by the inverse Fast Fourier Transform processor.

3.   An OFDM receiver as claimed in claim 1, further comprising:

-12-

a channel estimator, for compensating the frequency domain vector to produce a compensated frequency domain vector.

4.   An OFDM receiver as claimed in claim 1, wherein the output device comprises means for exploiting and cancelling any error control strategies applied in a transmitter of the received signals, and further comprising:

means for reapplying to the output data signal any error control strategies cancelled in the output device.

5.   An OFDM receiver as claimed in claim 4, wherein the output device comprises means for deinterleaving the compensated frequency domain vector.

6.   An OFDM receiver as claimed in claim 4, wherein the output device comprises means for demapping the compensated frequency domain vector.

7.   An adaptive decision feedback equalizer, comprising:

a first input, for a received signal comprising a plurality of symbols, the symbols representing an OFDM signal, each OFDM symbol comprising a plurality of sub-symbols per OFDM symbol period;

a feedforward stage, comprising a first number of taps and corresponding tap coefficients;

a feedback stage, comprising a second number of taps and corresponding tap coefficients;

a first buffer, for storing past symbols beyond symbols present in the feedforward stage;

a second buffer, for storing past symbols beyond symbols present in the feedback stage;

a correction algorithm processor, for updating tap coefficients of taps in the feedback stage and the feedforward stage at intervals of the OFDM symbol period.

8.   A method of adapting coefficients of an

adaptive equalizer, the equalizer comprising:

a first input, for a received signal comprising a plurality of symbols, the symbols representing an OFDM signal, each OFDM symbol comprising a plurality of sub-
5   symbols per OFDM symbol period;

a second input, for receiving a feedback signal comprising an estimate of a transmitted signal;

a feedforward stage, comprising a first number of taps and corresponding tap coefficients;

10   a feedback stage, comprising a second number of taps and corresponding tap coefficients;

a first buffer, for storing past symbols beyond symbols present in the feedforward stage;

a second buffer, for storing past symbols beyond
15   symbols present in the feedback stage; and

a correction algorithm processor, for updating tap coefficients of taps in the feedback stage and the feedforward stage at intervals of the OFDM symbol period, the method comprising:

20   supplying the feedback signal to the second input once per symbol period;

calculating required corrections to the tap coefficients corresponding to intervals of the sub-symbol period; and

25   updating the tap coefficients of the taps at intervals of the OFDM symbol period based on all calculated corrections obtained during each said period.

9.   A method as claimed in claim 8, further
30   comprising outputting an equalized signal at intervals of the symbol period.

(51) International Patent Classification ^{7} : H04L 27/26, 25/03	**A1**	(11) International Publication Number: **WO 00/44144** (43) International Publication Date: 27 July 2000 (27.07.00)

(54) Title: OFDM RECEIVER WITH ADAPTIVE EQUALISER
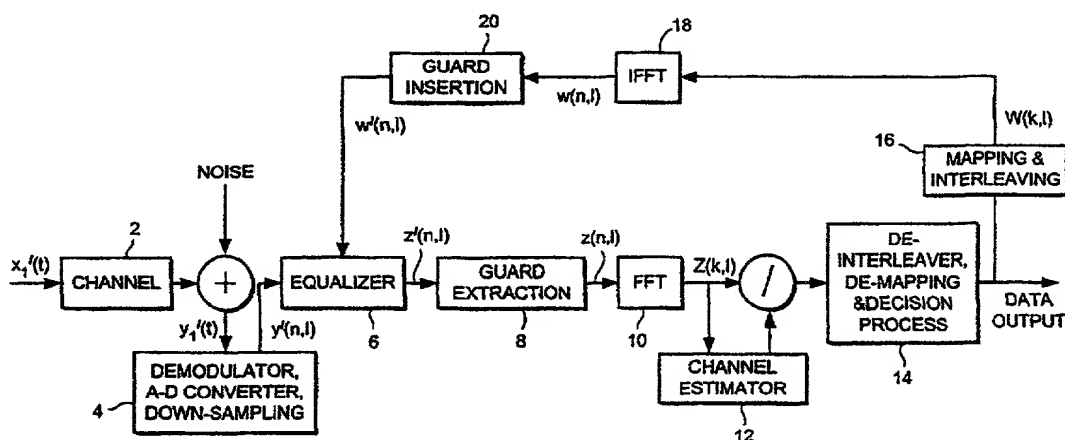
(57) Abstract

An OFDM receiver includes an adaptive equalizer, which acts on a received signal, after conversion to digital samples. After filtering by the equalizer, any guard interval is removed, and a Fast Fourier Transform is applied to the signal. The data signal is then estimated and the estimated data is supplied as an output. The estimated data also has any guard interval reinserted, and is applied to an Inverse Fast Fourier Transform, and is fed back to the equalizer to allow adaptation of the tap coefficients thereof.
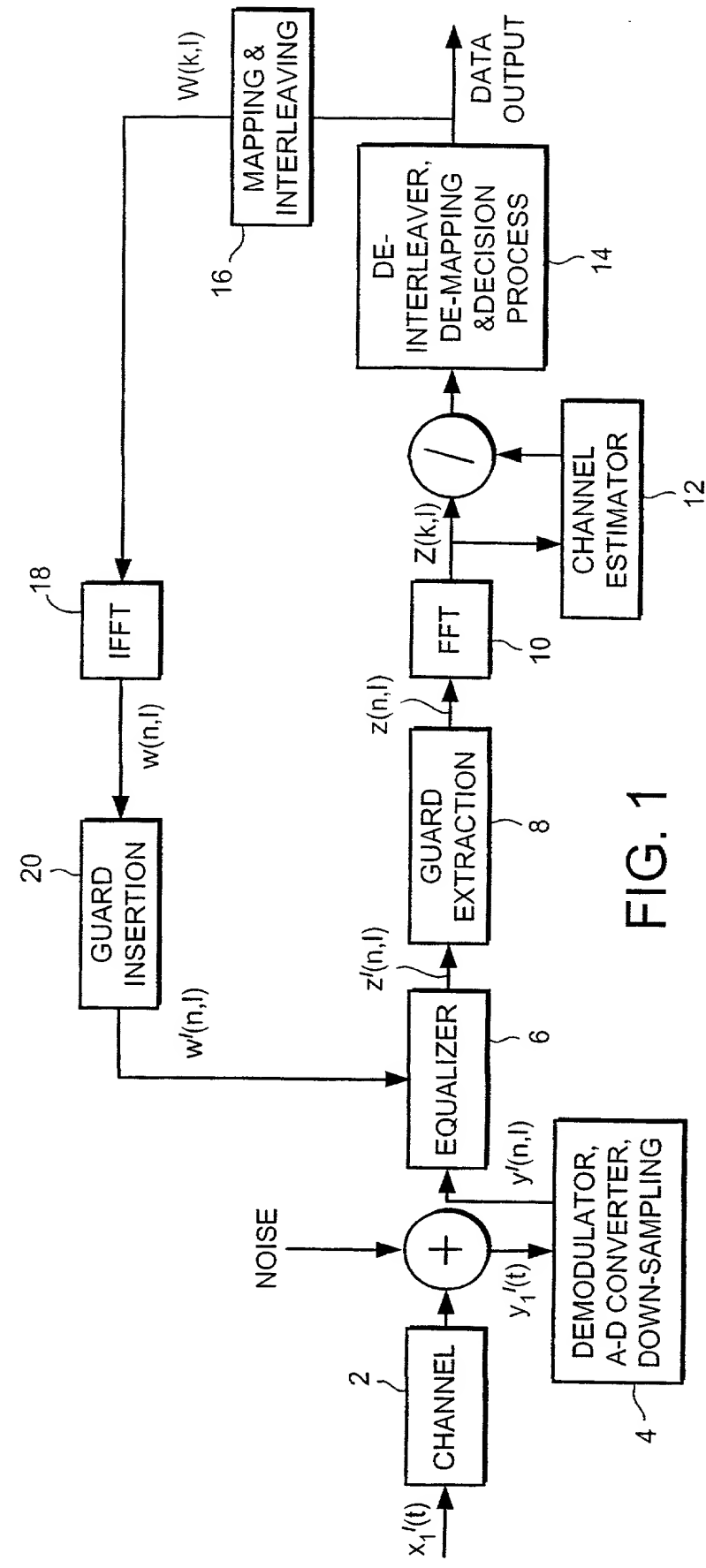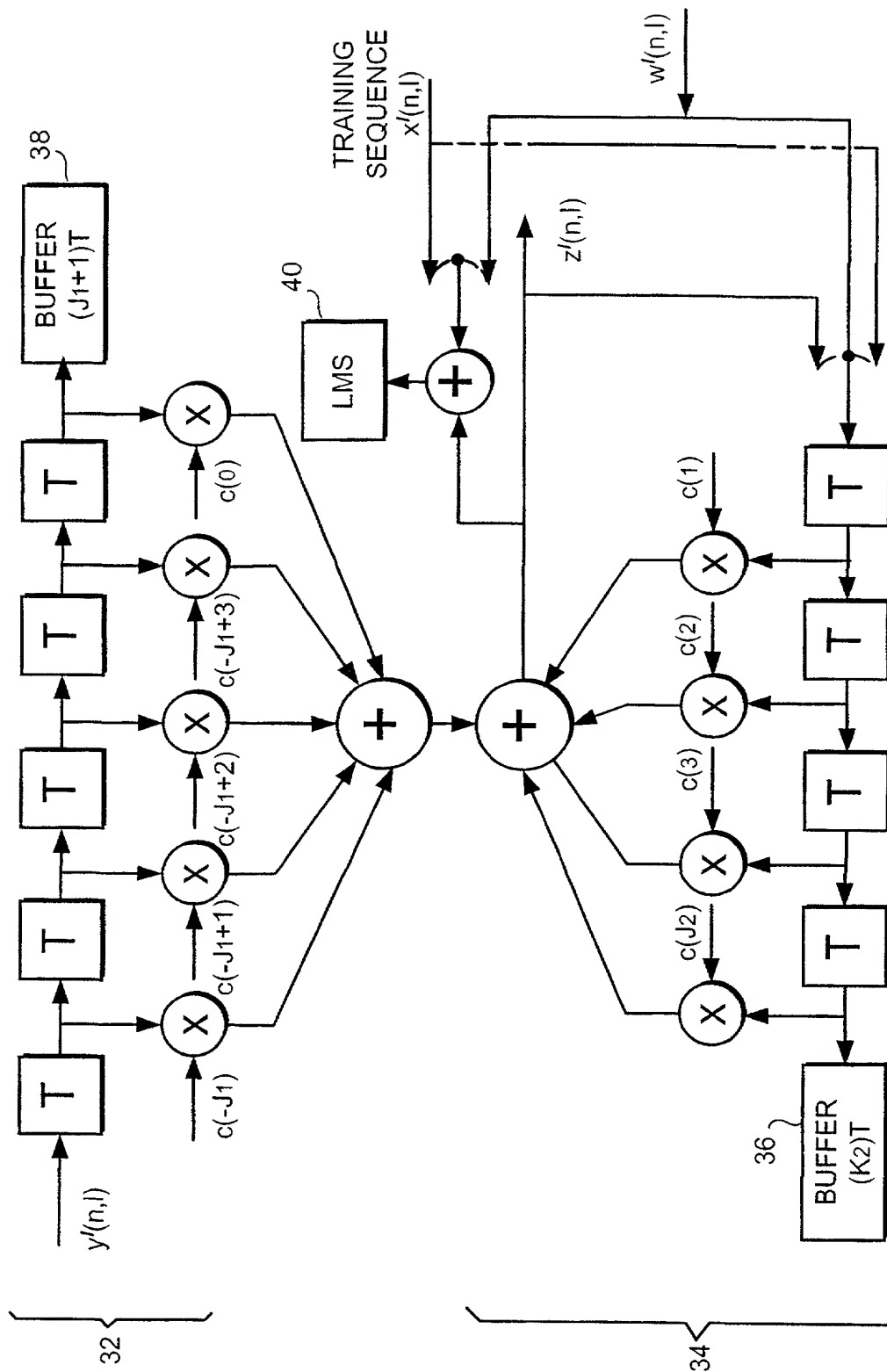
1 / 4

FIG. 1

FIG.2

FIG. 3

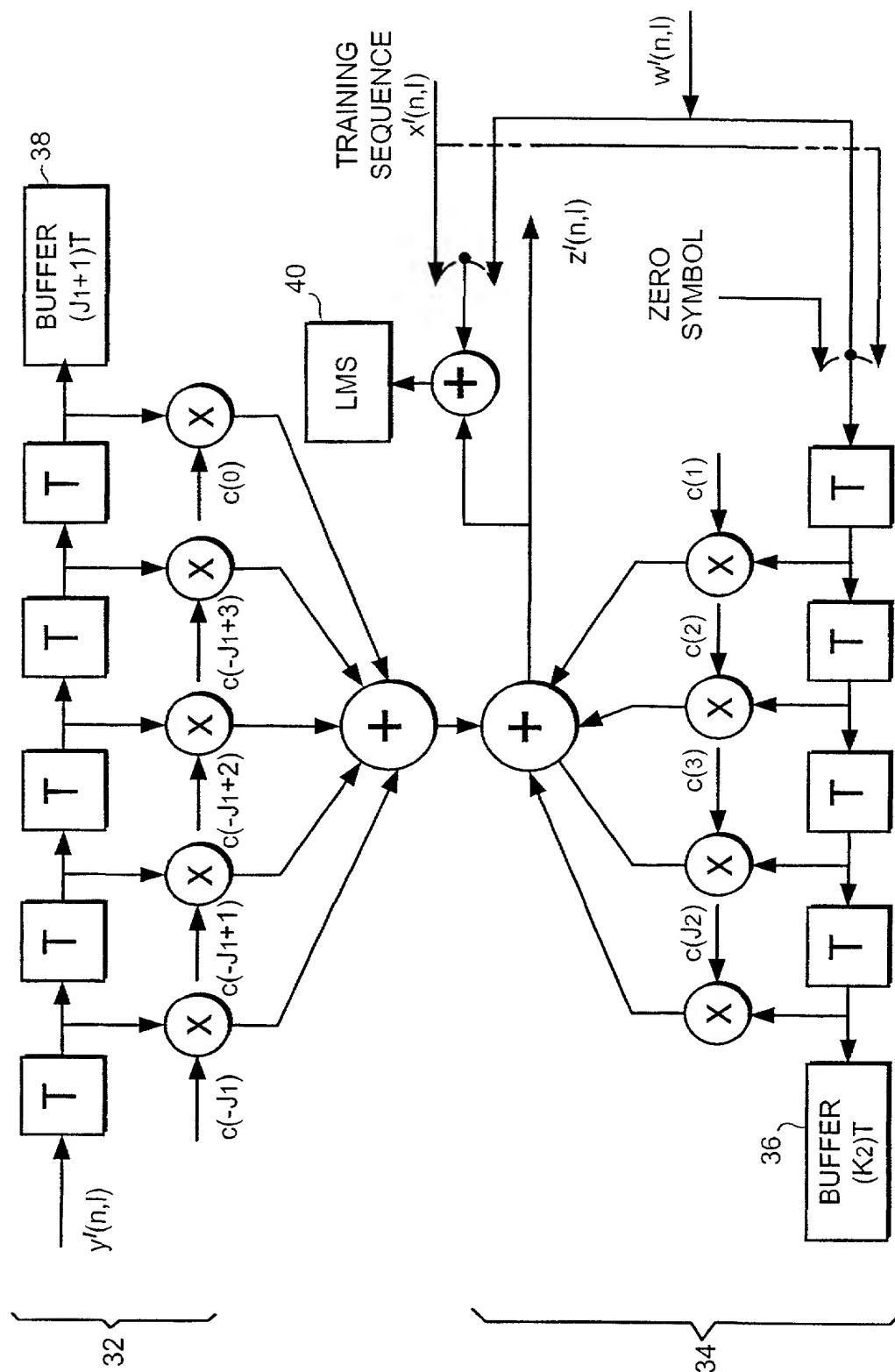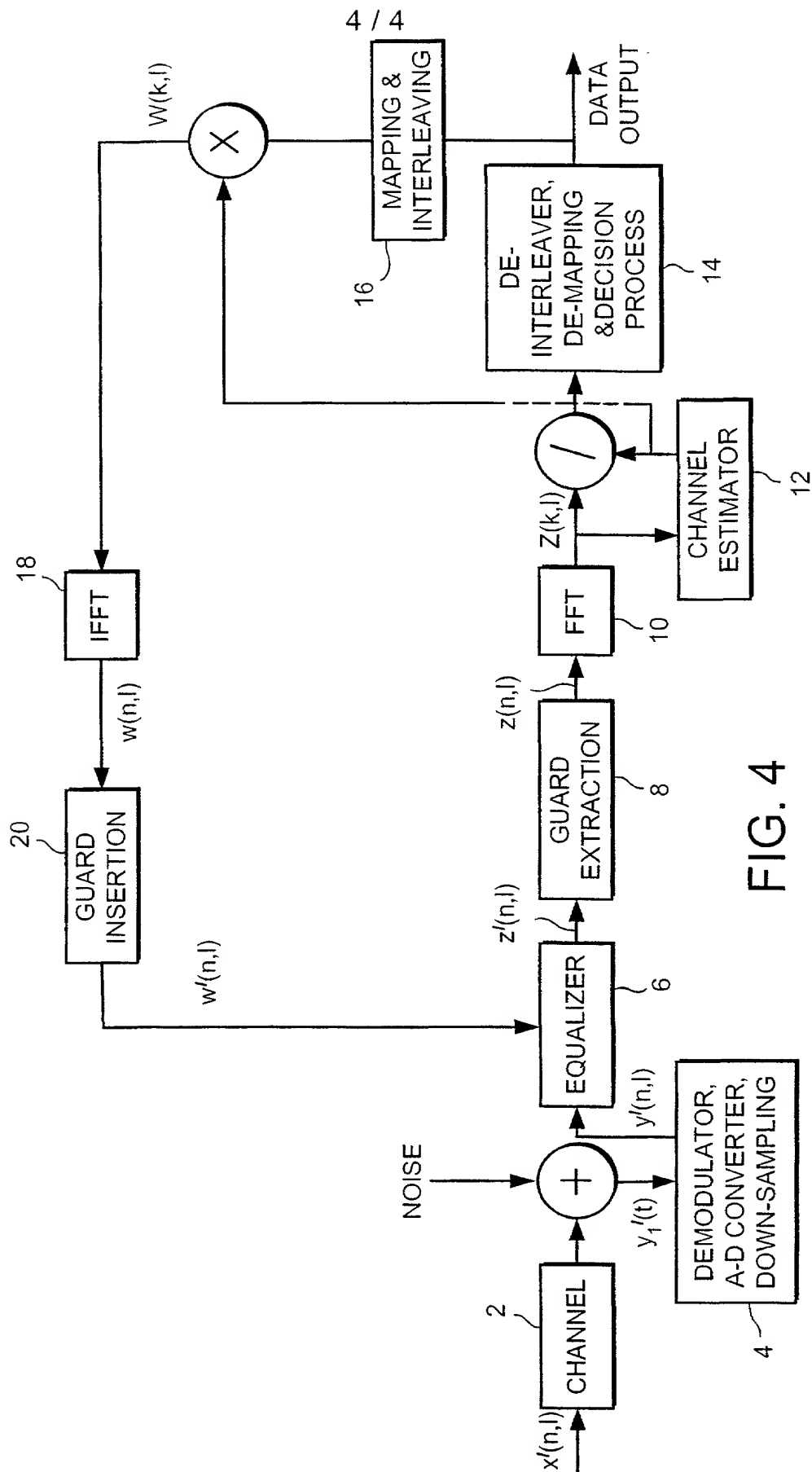4 / 4

FIG. 4

DECLARATION

As a below named inventor, I declare that:

My residence, post office address and citizenship are as stated below next to my name; I believe I am the original, first and sol inventor (if only one name is listed below) or an original, first and joint inventor (if plural inventors are named below) of the subjec matter which is claimed and for which a patent is sought on the invention entitled: OFDM RECEIVER WITH ADAPTIVI EQUALISER the specification of which was filed on 16 August 2001 as Application No. 09/913,840 and was amended o _____ (if applicable).

I have reviewed and understand the contents of the above identified specification, including the claims, as amended by an amendment referred to above. I acknowledge the duty to disclose information which is material to patentability as defined in Title 37 Code of Federal Regulations, Section 1.56. I claim foreign priority benefits under Title 35, United States Code, Section 119 of an foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for paten or inventor's certificate having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)

Country	Application No.	Date of Filing	Priority Claimed Under 35 USC 119
Great Britain	9901491.2	22 January 1999	Yes
PCT	PCT/GB00/00174	24 January 2000	Yes

I claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as th subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided b the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose material information as defined u Title 37, Code of Federal Regulations, Section 1.56 which occurred between the filing date of the prior application and the national o PCT international filing date of this application:
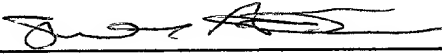
Application No.	Date of Filing	Status

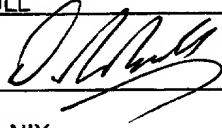| Full Name of Inventor 1:	Last Name: **ARMOUR**	First Name: **Simon**	Middle Name or Initial:	
Residence & Citizenship:	City: **Bath** _GBX_	State/Foreign Country: **Great Britain**	Country of Citizenship: **Great Britain**	
Post Office Address:	Post Office Address: **689 Wellsway Odd Down**	City: **Bath**	State/Country: **Great Britain**	Postal Code: **BA2 2TZ**
Full Name of Inventor 2:	Last Name: **BULL**	First Name: **David**	Middle Name or Initial: **Roger**	
Residence & Citizenship:	City: **Nr. Chepstow** _GBX_	State/Foreign Country: **Great Britain**	Country of Citizenship: **Great Britain**	
Post Office Address:	Post Office Address: **Netherways Netherhohpe Land Tidenham**	City: **Nr. Chepstow**	State/Country: **Great Britain**	Postal Code: **Monmouthsire NP16 7JE**

3-02

Full Name of Inventor 32:	Last Name: **NIX**	First Name: **Andrew**	Middle Name or Initial: **Robert**	
Residence & Citizenship:	City: **Bristol** GBX	State/Foreign Country: **Great Britain**	Country of Citizenship: **Great Britain**	
Post Office Address:	Post Office Address: **7 Bellview Clifton**	City: **Bristol**	State/Country: **Great Britain**	Postal Code: **BS8 1DA**

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and beli are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like : made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willf false statements may jeopardize the validity of the application or any patent issuing thereon.

Inventor one ___ Simon ARMOUR ___ Date: _18.12.01_

Signature: _____ Citizen of: Great Britain

Inventor two David Roger BULL ___ Date: _17/12/01_

Signature: _____ Citizen of: Great Britain

Inventor three Andrew Robert NIX ___ Date: _17/12/01_

Signature: _____ Citizen of: Great Britain

DE 7054023 v1